

CLAIMS

1. A method of exposure projecting and exposing a pattern formed on a mask on to a photosensitive substrate through a projection optical system, comprising the steps of:

measuring a position of an image projected by said projection optical system; and

projecting and exposing said pattern of the mask in a state with imaging characteristics corrected to reduce an amount of offset of a position of said projected image from an ideal position.

2. A method of exposure as set forth in claim 1, comprising the additional step of forming a mark on said mask, wherein said image to be measured in said measuring step is a projected image of said mark of the mask.

3. A method of exposure as set forth in claim 1, wherein said image to be measured in said measuring step is a projected image of the pattern formed on said mask.

4. A method of projecting and exposing a pattern formed on a mask on to a photosensitive substrate through a projection optical system, comprising the steps of:

forming a first mark on said mask;

measuring a position of an image projected by  
said projection optical system of a second mark of a  
control use reference mask formed with said second  
mark and a third mark corresponding to said first mark  
5 and defining it as a second image position,

finding the position of an image projected by  
said projection optical system of said third mark in a  
state with imaging characteristics preliminarily  
corrected to reduce an amount of offset of said second  
10 image position from an ideal position and defining it  
as a third image position;

measuring a position of an image projected by  
said projection optical system of said first mark of  
said mask and defining it as a first image position;

15 and

projecting and exposing said pattern of the  
mask in a state with imaging characteristics corrected  
so that said first image position becomes one of a  
predetermined positional relationship with said third  
20 image position.

5. A method of exposure as set forth in claim 4,  
wherein:

said first mark is formed at a peripheral area  
of a pattern area of the mask in which said pattern is  
25 formed;

said second mark is formed in a first area corresponding to said pattern area of said control use reference mask; and

5       said third mark is formed in a second area corresponding to said peripheral area of said control use reference mask.

10       6. A method of exposure as set forth in claim 4, wherein said predetermined positional relation is a relation where said first image position is in register with or in proximity to said third image position.

15       7. A method of exposure as set forth in claim 4, comprising the additional step of measuring in advance an amount of offset of the position of said first mark of said mask and the position of said third mark of said control use reference mask and defining it as a correction value,

20       wherein said predetermined positional relation is a relation where said first image position is substantially in register with a position of said third image position corrected by said correction value.

25       8. A method of exposure as set forth in claim 4, wherein said first to third marks are marks for measurement of a spatial image and in that the

positions of the images projected by said projection optical system of said first to third marks are measured by a spatial image measurement method.

9. A method of exposure as set forth in claim 4,  
5 wherein the positions of the images projected by said projection optical system of said first to third marks are measured for at least one component among a first direction parallel to an optical axis of said projection optical system, a second direction  
10 orthogonal to said first direction, and a third direction orthogonal to said first and second directions.

10. A method of exposure as set forth in claim 4, wherein said imaging characteristics are corrected  
15 by adjusting at least one of a projection magnitude of said projection optical system, an aberration of said projection optical system, a position of said mask with respect to said projection optical system, and a position of said photosensitive substrate with respect  
20 to said projection optical system.

11. A method of exposure as set forth in claim 8, wherein said first to third marks are comprised of mark elements comprised of a plurality of arrayed slits or pinholes.

12. A method of exposure as set forth in claim

11, wherein said first to third marks are comprised of a plurality of types of mark elements differing from each other in thickness of said slits or size of said pinholes and intervals and by selecting at least one  
5 of said plurality of types of mark elements to measure the position of a projected image.

13. A method of exposure as set forth in claim 4, wherein a plurality of said second marks of said control use reference mask are dispersed over said  
10 first area.

14. A method of exposure as set forth in claim 13, wherein said imaging characteristics are preliminarily corrected so as to give to the smallest sum of the squares of the amounts of offset of  
15 positions of images projected by said projection optical system of said second marks from their ideal positions multiplied with weighting coefficients.

15. A method of exposure as set forth in claim 14, wherein said weighting coefficients are the same  
20 for each of said second marks.

16. A method of exposure as set forth in claim 14, wherein said weighting coefficients differ in accordance with the positions of said second marks in said first area.

17. A method of exposure as set forth in claim

16, wherein said weighting coefficients are selected to become successively larger or successively smaller as the positions of the second marks in the first area move to the outside.

5           18.       A method of exposure dividing an enlarged pattern of a pattern for transfer into patterns of a plurality of masks and projecting and exposing images reduced by a projection optical system of said patterns of a plurality of masks on a surface of a  
10       photosensitive substrate while stitching them, said method of exposure comprising the steps of:

              forming a first mark in a peripheral area of a pattern area of said mask in which a pattern is formed;

15           measuring a position of an image projected by said projection optical system of a second mark of a control use reference mask formed with a plurality of said second marks in a first area corresponding to said pattern area of said mask and formed with a third  
20       mark facing said first mark in a second area corresponding to said peripheral area of said mask and defining it as a second image position;

              finding a position of an image projected by said projection optical system of said third mark in a  
25       state with the imaging characteristics preliminarily

corrected to reduce the amount of offset of said  
second image positions from their ideal positions and  
defining it as a third image position;

measuring a position of an image projected by  
5 said projection optical system of said first mark of  
said mask and defining it as a first image position;  
and

successively projecting and exposing patterns  
of said masks in a state with imaging characteristics  
10 corrected so that said first image position becomes in  
register with or proximity to said third image  
position.

19. A method of exposure as set forth in claim  
18, wherein said mask is a master mask and said  
15 photosensitive substrate is a substrate for production  
of a mask.

20. A method of exposure as set forth in claim  
18, wherein said mask is a working mask and said  
photosensitive substrate is a substrate for production  
20 of a device.

21. A method of exposure as set forth in claim  
18, wherein:

said imaging characteristics are preliminarily  
corrected so as to give to the smallest sum of the  
25 squares of the amounts of offset of positions of

images projected by said projection optical system of  
said second marks from their ideal positions  
multiplied with weighting coefficients; and

5        said weighting coefficients are selected so  
that ones for second marks positioned at portions in  
said first areas in proximity to sides to be stitched  
with other masks are larger and ones for the remaining  
portions are smaller.

22.        A method of exposure projecting and  
10        exposing a pattern formed on a mask on to a  
photosensitive substrate through a projection optical  
system, comprising the steps of:

15        making part or all of said pattern reach a  
peripheral area of a pattern area of said mask in  
which a pattern is formed and defining the portion of  
said pattern present at said peripheral area as a mark  
portion for measurement of a spatial image;

20        measuring a position of an image projected by  
said projection optical system of said mark portion of  
said mask by a spatial image measurement method; and

25        correcting imaging characteristics so as to  
give the smallest amount of offset of the image  
position of said mark portion from its ideal position  
and exposing and projecting the pattern of said mask  
in a state with the mark portion blocked by a blind.



23. An exposure apparatus for projecting and exposing a pattern formed on a mask on to a photosensitive substrate through a projection optical system, comprising:

5 a mask stage which selectively or simultaneously holds a mask having a pattern area in which a pattern to be transferred is formed and a peripheral area of said pattern area in which a first mark for spatial image measurement is formed and a control use reference mask having a first area  
10 corresponding to said pattern area of said mask in which a second mark for spatial image measurement is formed and a second area corresponding to said peripheral area in which a third mark for spatial  
15 image measurement facing said first mark is formed;

a substrate stage which holds a photosensitive substrate as an object for exposure;

a drive which moves said mask stage and said substrate stage;

20 a spatial image measurement device which has a light receiver provided at said substrate stage;

an adjuster which adjusts imaging characteristics; and

a controller which measures a position of an  
25 image projected by said projection optical system of

said second mark of said control use reference mask by  
said spatial image measurement device and defines it  
as a second image position, measures a position of an  
image projected by said projection optical system of  
5 said third mark in a state with imaging  
characteristics preliminarily corrected by said  
adjuster so as to give the smallest amount of offset  
of said second image position from its ideal position  
and defines it as a third image position, and controls  
10 the apparatus to transfer the pattern of said mask on  
to said photosensitive substrate in a state with  
imaging characteristics corrected by said adjuster so  
that said first image position becomes in register  
with or in proximity to said third image position.

24. A method of exposure dividing an enlarged  
pattern of a pattern for transfer into patterns of a  
plurality of master masks and projecting and exposing  
images reduced by a projection optical system of said  
patterns of a plurality of master masks on a surface  
20 of a mask substrate while stitching them, said method  
of exposure comprising the steps of:

finding a displacement of an actually projected  
point on said mask substrate from an ideal projected  
point; and

making at least part of the pattern formed on

said master mask distort based on the found displacement or making the position of the pattern of said master mask at the object plane side of said projection optical system shift.

5           25.       A method of exposure as set forth in claim 24, wherein said displacement is displacement caused by at least one of deformation of the pattern of said master mask, aberration of said projection optical system, and deformation of said mask substrate.

10           26.       A method of exposure projecting an image of a pattern of a master mask on a mask substrate by a first projection optical system to produce a working mask and projecting and exposing an image of the pattern of said working mask on a device substrate on  
15           which a microdevice is to be formed by a second projection optical system, said method of exposure comprising the steps of:

              finding at least one of a displacement of an actually projected point on said mask substrate from  
20           an ideal projected point and a displacement of an actual projected point on said device substrate from an ideal projected point; and

              making at least part of the pattern formed on said master mask distort based on the found  
25           displacement or making the position of the pattern of

said master mask at the object plane side of said projection optical system shift.

27. A method of exposure as set forth in claim 26, comprising the additional steps of dividing an enlarged pattern of a pattern for transfer into patterns of a plurality of masks and successively transferring reduced images of the patterns of the plurality of master masks on the surface of said mask substrate while stitching them.

28. A method of exposure as set forth in claim 26, wherein said displacement is displacement caused by at least one of deformation of the pattern of said master mask, aberration of said first projection optical system, deformation of said mask substrate, deformation of the pattern of said working mask, and aberration of said second projection optical system.

29. A photomask produced by using the method of exposure as set forth in claim 1.

30. A photomask produced by using the method of exposure as set forth in claim 4.

31. A photomask produced by using the method of exposure as set forth in claim 18.

32. A photomask produced by using the method of exposure as set forth in claim 22.

33. A microdevice produced by using the method of exposure as set forth in claim 1.

34. A microdevice produced by using the method of exposure as set forth in claim 4.

5 35. A microdevice produced by using the method of exposure as set forth in claim 18.

36. A microdevice produced by using the method of exposure as set forth in claim 22.

10 37. A method of producing a photomask on which a pattern for transfer is formed, comprising the steps of:

dividing an enlarged pattern of said pattern for transfer into patterns of a plurality of master masks;

15 forming an alignment mark on a surface of a substrate for said photomask; and

successively transferring reduced images of the patterns of the plurality of master masks on the surface of the substrate for said photomask while stitching them while aligning said photomask substrate and said master mask using said alignment mark.

20 38. A photomask having an alignment mark for alignment produced by using the method of producing a photomask as set forth in claim 37.

25 39. A method of exposure projecting a pattern

of a photomask as set forth in claim 38 on to a device substrate, comprising the step of

aligning said photomask and said device substrate using said alignment mark of said photomask.

5           40.       An exposure apparatus comprising:

a mask magazine which stores a plurality of master masks;

a mask stage which carries one master mask selected from said mask magazine;

10           a projection optical system which projects a reduced image of the pattern of the master mask carried on said mask stage on to a photomask substrate formed with an alignment mark;

15           a substrate stage which positions said photomask substrate on a plane vertical to an optical axis of said projection optical system; and

20           an alignment system which aligns said master mask on said mask stage and said photomask substrate on said substrate stage using said alignment mark of said photomask substrate on said substrate stage so as to stitch the reduced images of the patterns of the plurality of master masks on said photomask substrate.

25           41.       An exposure apparatus projecting an image of a pattern on a photomask as set forth in claim 40 on to a device substrate, comprising:

a mask stage which carries said photomask;

a projection optical system which projects a reduced image of a pattern of the photomask carried on the mask stage on to the device substrate;

5 a substrate stage which positions said device substrate on a plane vertical to an optical axis of said projection optical system; and

10 an alignment system which aligns said photomask on said mask stage and said device substrate on said substrate stage using said alignment mark of said photomask on said mask stage so as to project the pattern of said photomask on the said device substrate.

15 42. A method of production of a microdevice comprising the steps of:

forming an alignment mark on a first photomask substrate;

20 dividing a device pattern to be transferred on to a second substrate on which the microdevice is to be formed into a plurality of element patterns;

transferring reduced images of said plurality of element patterns on to said first substrate to form a device pattern using positional information obtained by detecting said alignment mark; and

25 transferring said device pattern on to said

second substrate using said alignment mark of the photomask on which said device pattern is formed.

43. A method of exposure using a plurality of masks to transfer patterns on a photosensitive substrate in a plurality of partially overlapping areas, wherein an amount of exposure at part of said plurality of areas at the time of transfer of said pattern is different from an amount of exposure at other areas.

44. A method of exposure as set forth in claim 43, wherein said amount of exposure is determined in accordance with an amount of change of line width of patterns to be transferred to said plurality of areas.

45. A method of exposure as set forth in claim 43, wherein said amount of exposure is determined in accordance with a time from transfer of said patterns to development of said photosensitive substrate.

46. A method of exposure as set forth in claim 43, wherein the patterns to be transferred to said plurality of areas are formed on different masks from each other and the amounts of exposure at the plurality of areas are different from each other.

47. A method of production of a photomask including the step of transferring a plurality of patterns on to a photomask substrate by a step-and-



stitch method using the method of exposure as set forth in claim 43.

48. A method of production of a device including the step of transferring a plurality of patterns on to a device substrate by a step-and-stitch method using the method of exposure as set forth in claim 43.

49. A method of exposure emitting an illumination beam to a mask and exposing a photosensitive substrate by said illumination beam through a projection optical system, said method of exposure comprising the steps of:

detecting an image projected by said projection optical system at a plurality of different points in an area illuminated by said illumination beam to obtain first information, adjusting optical characteristics of said projected image based on the same, detecting an image projected by said projection optical system at least at one measurement point outside of said illuminated area in a state with said optical characteristics adjusted to obtain second information, and storing the same; and

adjusting characteristics of the pattern image by said projection optical system using said second information so as to expose said photosensitive

substrate by said illumination beam using said mask.

50. A method of exposure as set forth in claim 49, comprising the additional steps of detecting a mark arranged outside of said illuminated area on said mask and adjusting characteristics of said pattern image based on said second information and third information obtained by detection of said mark.

51. A method of exposure as set forth in claim 50, wherein said mark is formed at a plurality of different positions outside a pattern area of said mask on which the pattern to be transferred to said photosensitive substrate is formed.

52. A method of exposure as set forth in claim 51, wherein a specific mask different from said mask is used to obtain said first and second information.

53. A method of exposure as set forth in claim 52, wherein said specific mask has a first area corresponding to said pattern area and a second area outside of the same in each of which a plurality of marks are formed, said first information is obtained by detection of marks in said first area, and said second information is obtained by detection of marks in said second area.

54. A method of production of a device including the step of transferring a device pattern on

to a workpiece using the method of exposure as set forth in claim 49.

55. A method of production of a photomask including the step of transferring patterns formed on a plurality of master masks on to a photomask substrate by a step-and-stitch method using the method of exposure as set forth in claim 49.

56. A method of production of a photomask as set forth in claim 55, including the additional steps of reducing and projecting the patterns of the master masks through said projection optical system, enlarging a device pattern to be formed on said photomask by exactly an inverse magnification of a projection magnification of said projection optical system, dividing said enlarged pattern into elements or functions, and forming the same on said plurality of master masks.

57. A method of production of a photomask for use in an exposure apparatus, comprising the steps of exposing a plurality of partially overlapping areas on a substrate for said photomask using a plurality of master masks formed by dividing an enlarged pattern of a device pattern to be formed on said photomask into a plurality of sections and adjusting at least one of a shape and position

of a reduced image of a divided pattern on said substrate based on transfer characteristics of said master masks by said exposure apparatus.

5 58. A method of production of a photomask as set forth in claim 57, comprising the additional steps of modifying design data of said divided pattern produced from said enlarged pattern and forming said divided pattern on said master mask in accordance with said modified design data.

10 59. A method of production of a photomask as set forth in claim 57, comprising the additional step of adjusting optical characteristics of a projection optical system forming a reduced image of said divided pattern based on said transfer characteristics.

15 60. A method of production of a photomask as set forth in claim 57, comprising the additional steps of transferring said divided pattern on said substrate by synchronously moving said master mask and said substrate for scan exposure of said plurality of areas  
20 and adjusting the shape of said reduced image by changing conditions of said scan exposure based on said transfer characteristics.

25 61. A method of transfer dividing a pattern for transfer into patterns for a plurality of masks and successively transferring the patterns of the masks on

to an object through a projection optical system while stitching the patterns, said method of transfer comprising the step of transferring the patterns of the masks on to the object in a state that a  
5 correction amount of imaging characteristics of projection image obtained by the projection optical system is different between a stitching area of the divided patterns and the other area except the stitching area.

10 62. A method of transfer as set forth in claim 61, wherein the stitching area of the divided patterns is a peripheral area in a pattern area formed on the mask and the other area is a center area in the pattern area.

15 63. A method of transfer as set forth in claim 61, wherein transfer conditions for the divided patterns are different from each other according to shapes of the divided patterns.

20 64. A method of transfer as set forth in claim 63, wherein the shapes of the divided patterns are line-widths.

25 65. A method of transfer as set forth in claim 61, wherein an enlarged pattern of the pattern for transfer is divided and the divided patterns are formed on the respective masks.

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69. A method of producing a device comprising the step of using the method of transfer as set forth in claim 61.